0005417742 & & *Drawing available*
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Insulating-liquid immersed electrical machine - maintains pressure of cooling liquid in tank and prevents vaporisation using flexible sheet which is expanded into tank by pressurised gas
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CN 1048767	A	19910123				199140	E
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US 5324886	A	19940628	US 1990550580	A	19900710	199425	E
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Alerting Abstract EP A
The pressure of an insulating liquid (5) in a tank (1) containing an electrical machine (4) is maintained by an impermeable deformable flexible sheet (72) which is caused to balloon into the tank under the influence of a volume of pressurised gas (73) or a spring acting on it to adjust the

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volume of the tank. The flexible sheet (72) may be formed as bellows, a flat sheet, or a balloon shaped body in the tank or a separate auxiliary tank communicating with the main tank.
The insulating liquid may be a perfluorocarbon liquid or mineral oil, and its pressure is set to a level preventing it from vaporising when its temperature is raised by heat from the electrical machine.
USE - In tanks for electrical inductors with iron cores cooled by insulating liquids. @(11pp Dwg.No.1/10)@

Title Terms /Index Terms/Additional Words: INSULATE; LIQUID; IMMERSE; ELECTRIC; MACHINE ; MAINTAIN; PRESSURE; COOLING; TANK; PREVENT; VAPORISE; FLEXIBLE; SHEET; EXPAND; PRESSURISED; GAS

[54]发明名称　浸在绝缘液体中的电器

[57]摘要

　　根据本发明，一个浸入绝缘液体的电器其组成为，一个电器，一个包含该电器的密封液罐，被安置在电器与液罐间的绝缘液体，在这里，液罐包括可变形装置，气体和液体不能通过该装置，该装置的形状是可变化的使得一个能接收液罐与电器间的绝缘液体的接收容积也是可变化的，绝缘液体完全充满液罐中的这个接收体积，浸入绝缘液体的电器进一步的组成有加压装置，该装置用于调节可变形装置，使得液罐中的绝缘液体的压力被保持在一适当程度用以防止绝缘液体汽化。
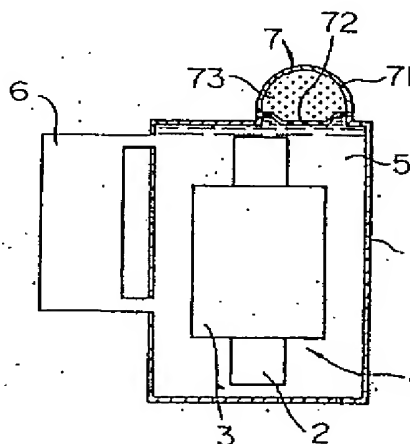
1．一个浸入绝缘液体的电器其组成是，一个电器，一个包含该电器的密封液罐，被安置在电器与液罐间的绝缘液体，在这里液罐包括可变形装置，气体和液体不能通过该装置，该装置与液罐一起形成一能够接收液罐与电器间绝缘液体的接收容积，该装置的形状是可变化的使得接收容积也可变化。绝缘液体完全充满液罐中的接收体积，浸入绝缘液体的电器进一步的组成有加压装置，该装置用于调节可变形装置使得液罐中的绝缘液体被保持在一适当程度来防止绝缘液体汽化。

2．一个根据权利要求1的浸入绝缘液体的电器，在这里由加压装置所增压的绝缘液体的压力是大于大气压的。

3．一个根据权利要求1的浸入绝缘液体的电器，在这里加压装置是压迫可变形装置的被加压气体。

4．一个根据权利要求1的浸入绝缘液体的电器，在这里加压装置是一个压迫可变形装置的弹簧。

5．一个根据权利要求1的浸入绝缘液体的电器，在这里可变形装置是一个与液罐一起形成接收容积的韧性薄片。

6．一个根据权利要求1的浸入绝缘液体的电器，在这里可变形装置是一与液罐一起形成接收容积的波纹管。

7．一个根据权利要求1的浸入绝缘液体的电器，在这里可变形装置是一气球状构件，加压装置是放入气球状构件的被加压气体。

8．一个根据权利要求7的浸入绝缘液体的电器，在这里气球状

构件被包含在液罐中。

9．一个根据权利要求7的浸入绝缘液体的电器，在这里浸入绝缘液体的电器包括一与液罐相通的箱。气球状构件被包含在箱内。

10．一个根据权利要求1的浸入绝缘液体的电器，在这里绝缘液体是不可燃的。

11．一个根据权利要求1的浸入绝缘液体的电器，在这里绝缘液体是全氟碳液体（perfluorocarbon）。

12．一个根据权利要求1的浸入绝缘液体的电器，在这里浸入绝缘液体的电器进一步包括一第二液罐和一压力响应排出阀。该阀只有当液罐的压力是大于所预定的度数为使液罐压力降低时才将第二液罐与液罐连通起来。

浸在绝缘液体中的电器

本发明涉及一种电器，这种电器被浸入不可燃绝缘液体中，以此来冷却该电器并增加电器的绝缘性。

以前一项关于被浸入绝缘液体中的电感器的工艺，正如日本专利申请公开第63-241909号中示出的，其组成为一个含有一个铁芯及一个感应线圈的电感器体，一个密封液罐。在该液罐中放有该电感器体，不可燃绝缘液体充满了电感器体与密封液罐间空间的一部分来浸没里面的电感器体，空间的另一部分充满被加压的绝缘气体。加压绝缘气体的一部分在不可燃绝缘液体中被吸收，结果加压绝缘气体的体积在液罐中减小。在上述以前关于浸在绝缘液体中电感器的工艺中，当由于液罐中温度的降低而引起密封液罐中压力降低时，被吸收的绝缘气体返回气体，结果绝缘液体包含许多气泡在里面。由于绝缘气体的绝缘强度低于被涂覆的电感器线圈间的绝缘液体，这些绝缘气体气泡引起电感器中绝缘强度的降低。

本发明之目的是提供一个浸在绝缘液体中的电器，在这个电器中绝缘液体不包含或吸收气体而且被防止汽化。

根据本发明，一个被浸入绝缘液体的电器其组成为，一个电器，一个包含该电器的密封液罐，被放置在电器与液罐间的绝缘液体，在这里液罐包含一个可变形装置，气体与液体不能通过该装置，该装置的形状是可变的，结果能够接收液罐与电器间的绝缘液体的接收容积

也是可变的，绝缘液体完全充满液罐中的接收容积，而且该浸入绝缘液体的电器之进一步组成有用于调节可变形装置形状的加压装置。结果液罐中的绝缘液体的压力被保持在一适当程度来防止绝缘液体汽化。

在根据本发明的浸入绝缘液体中的电器里，由于液罐包含可变形装置，气体和液体不能通过该装置且该装置的形状是可变的所以能够接收液罐与电器间绝缘液体的接收容积是可变的，由于绝缘液体完全充满液罐中的接收容积，所以接收容积不包含气体在里面因而气体不会被接收容积中的绝缘液体所吸收。由于液罐含有可变形装置，该装置的形状可变化因而接收容积也可变化，所以可变形装置补偿了接收容积的变化，甚至在液罐的形状及电器与绝缘液体的体积由于温度的变化而变化时，也是如此。此外，由于浸入绝缘液体中的电器进一步由用于调节可变形装置的形状的加压装置组成，因而液罐中的绝缘液体的压力被保持在一适当程度来防止绝缘液体汽化。所以甚至在接收容积改变时，绝缘液体也不会汽化。因而，降低电器中绝缘强度的气泡在绝缘液体中也不会产生。

图1是一个部分剖面图示出了根据本发明的浸入绝缘液体的电器的一个实施例。

图2是一个示意截面图示出了（一个感应线图的一部分）它用在根据本发明的浸入绝缘液体的电器里。

图3是一曲线图示出了用在根据本发明的浸入绝缘液体的电器里的全氟碳（perfluorocarbon）液其沸点相对于绝对压力的特性。

图4和图5是部分剖面图，示出了根据本发明的浸入在绝缘液体的电器的可变形装置在形状上的改变，即可变形装置随温度的改变而

变形。

图6到图10是部分剖面图示出了根据本发明的浸入绝缘液体的电器的其他实施例。

在根据本发明的浸入绝缘液体的电器的一个实施例中，如图1所示，一个带有一铁芯2和一感应线圈3的电感器体4被包含在一密封液罐1中。不可燃并绝缘的液体与充满了液罐1与电感器体4间的容积来使电感器体4冷却并增加电感器体4中的绝缘强度。这个不可燃液体比如是全氟碳，其主要成分则$C_8F_{16}O$。液罐1包含有一散热器6用来使由电感器体4运行所加热的不可燃液体5冷却。液罐容积调节装置7被安置在液罐1的上部来调节能够接收绝缘液体5的容积以便使其能包电感器体4，并增加绝缘液体5的压力比如大于大气压。液罐容积调节装置7带有一个封密盖71，它被安装在液罐1及一个柔韧的或可变形的构件或薄片72上，气体及液体不能通过此构件，该构件与盖71一起限定了一个室73，并与液罐1一起限定了能够接收绝缘液体5的液罐容积。由于可变形构件72能够变形，能够接收液罐1中的绝缘液体5的容积也变化。被加压的气体73（室73与安置在其里面的气体以同一参考数码73来表示）被送入室73来压迫可变形构件72并调节可变形构件72的形状以便根据绝缘液体5的体积来调节液罐容积，液罐1中的绝缘液体5被加压比如大于大气压力（大约0·1MPa）并小于0·3MPa。气体73的压力被确定到使绝缘液体5的压力在一适当程度以防止绝缘液体5汽化，甚至在由于电感器体4或包围液罐1的空气的热量而引起的绝

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缘液体5的温度增加时也是如此。气体73可以是比如空气或绝缘气体或惰性气体。由于气体73和绝缘液体5不能通过可变形构件72且绝缘液体与完全充满能够接收液罐1中的绝缘液体5的液罐容积，所以绝缘液体5不包含或吸引气体。此外，甚至在绝缘液体5的温度增加和／或液罐中的绝缘液体5的压力降低时，也不产生气泡。

在如图2所示的感应线圈3的结构中，一个用于绝缘液体5的通道32在线圈3的涂覆电线31间辐射状扩展。该绝缘液体通道32的宽度在图2中由D来表示。

绝缘液体5在通道32中流动来冷却电感器体，绝缘液体5的温度因电感器体4运行所产生的热量而增加。被加热的绝缘液体5流向用于冷却绝缘液体5的散热器6，结果环绕电感器体4的绝缘液体5的温度被保持在一较低程度。此外，绝缘液体5能有效冷却电感器体4且绝缘液体5的绝缘特性并不降低。由于由加压气体通过可变形构件72对绝缘液体5加压比如大于0·1MPa而少于0·3MPa，绝缘液体5的沸点在一较高程度，如图3所示。因而，比如在感应线圈3的涂覆电线31间的绝缘液体通道32里，不产生汽化的绝缘液体的汽泡，甚至在电感器体4开始运行时或甚至在涂覆电线31里的电流迅速增加时，即甚至在绝缘液体5的温度迅速增加时，也是如此。以这种方式，绝缘液体5的绝缘强度总是保持在一高的程度上。

此外，虽然以前工艺中绝缘液体通道的宽度D大约为5mm，根据本发明的绝缘液体通道32的宽度D可以很小比如小于2mm，由于气体没有被绝缘液体5吸收，汽化的绝缘液体的汽泡就不产生，且全氟碳液体（$C_8F_{18}O$）的运动粘滞性0·8cts大大小于矿

物油的运动粘滞性 7 · 5 c t s。因而，电感器体 4 的尺寸可以很小。

如果绝缘液体 5 的压力及气体 7 3 的压力保持在 0 · 1 M P a 和 0 · 3 M P a 之间，则液罐 1 和盖 7 1 不需要一个用于抵抗压力的特殊结构。

当绝缘液体 5 是全氟碳液体时，由可变形构件 7 2 与盖 7 1 所确定的室 7 3 的适当容积如下面来确定。请参照图 4 和 5。根据玻义耳（B o y l e）和查理（C h a r l e s）定律，当周围温度 ϑ 为 −2 5 ℃，绝缘液体 5 的体积为 V_L，气体 7 3 的体积为 V_G，气体的压力是 P_{G1}，气体 7 3 的温度如图 4 所示为 T，当周围温度 ϑ' 为 8 0 ℃时，绝缘液体 5 的体积为 V_L'，气体 7 3 的体积为 V_G'，气体的压力是 P_G'，气体 7 3 的温度 T' 如图 5 所示，这些之间的关系用下列等式（1），（2）和（3）来表示。

$$(P_G * V_G) / T = (P_G' * V_G') / T \quad\quad ——(1)$$

$$V_G = x * V_L \quad\quad\quad\quad ——(2)$$

$$V_G' = x * V_L - V_L * \beta * (\vartheta' - \vartheta) \quad\quad ——(3)$$

（x 是 V_G 对于 V_L 的比率，β 是绝缘液体 5 的膨胀系数）
当等式（2）和（3）与（1）式结合时，

$$(P_G * x * V_L) / T = P_G' * V_L * \{x - \beta * (\vartheta' - \vartheta)\} / T \quad ——(4)$$

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$$X / X - \beta * (\vartheta' - \vartheta) = (P_G' * T) / (P_G * T') \quad —(5)$$

根据等式（5），当 P_G 是 0.1 MPa，T 为 253（273－20℃）K，ϑ 为－20℃，P_G' 是 0.3 MPa，T' 是 358（273＋85℃，ϑ' 是 85℃而 β 为 15.4*10-4（1／℃）时，

$$X = 0.3$$

因而，当周围温度 ϑ 是－25℃时，室73的适当体积是绝缘液体5的体积的30%。

在这个实施例中，改进了绝缘强度的可靠性，保持了稳定的绝缘特性。此外，感应线圈的尺寸可以是小的，液罐不需要用于抵抗压力的特别结构，而且可提供一个低成本的，浸入绝缘液体的电器。

根据本发明的浸入绝缘液体的电器的另一个实施例，如图6所示，带有一个液罐容积调节装置7，该装置包括一个箱74，箱74被可拆卸地安在液罐1上且其内部与浓罐相通，还包括一个气球形状的可变形构件75，该构件的体积是可变的，在该构件里加压气体73被加入来调节气球状可变形构件75用以对绝缘浓体5加压，而且该构件包含在箱74里。气体73和绝缘液体5不能通过可变形构件75，且绝缘液体5完全充满液罐1和箱74里的能够接收绝缘液体5的容积。箱74可被安置在液罐1的上部或其边侧部。在这个结构里，改进了绝缘强度，且由于浓罐容积调节装置7的可拆卸结构，在其运输期间流入绝缘液体的电器的尺寸可以是小的。

根据本发明的浸入绝缘液体中的电器之另一个实施例如图7所示

带有液罐容积调节装置7，该装置包括了一个气球形可形变构件75，构件的外部体积是可变的，在这个构件中加压气体73被放入来调节气球状可变形构件75的体积用以在一适当程度对绝缘液体5加压，而且该构件被包含在液罐1中。气体73和绝缘液体5不能通过可变形构件75且绝缘液体5完全充满在液罐1中能够接收包围电感器体4的绝缘液体5的容积。在这个结构中，改进了绝缘强度，绝缘液体5完成充满可接收液罐1中包围电感器体4，绝缘液体5完全充满可接收液罐1中包围电感器体4的绝缘液体5的容积，它的体积可以是小的。因此，浸入绝缘液体中的电器的尺寸是小的。

根据本发明的浸入绝缘液体中的电器的另一个实施例，如图8所示，具有在图1中示出的结构及被安置在电感器体4与液罐1间的固体绝缘构件10。在这种结构中，改进了绝缘强度，绝缘液体5之体积可以是小的，它完全充满了可接收液罐1中包围电感器体4的绝缘液体5的容积。由于所需绝缘液体5的体积是小的所以气体93的体积也可以是小的。因而，浸入绝缘液体的电器之尺寸是小的。

根据本发明，浸入绝缘液体中的电器的另一个实施例，如图9所示，具有带铁芯2和感应线图3的电感器体4及包含电感器体4和散热器6的密封液罐1。液罐容积调节装置7被安置在液罐1的上部。液罐容积调节装置7带有可变形构件72，该构件与液罐1的一部分71一起限定出室73，该构件与液罐1一起限定出能够接收绝缘液体5的液罐容积。加压气体被加入室73。绝缘液体5完全充满了液罐1中能接收绝缘液5的液罐容积。固体绝缘构件10被安置在电感器体4和液罐1之间。一个第二液罐11通过导管13和压力响应排

放阀12与室73相连。只有当室73的压力增至超过一预定度数时，压力响应排放阀12才将第二液罐11与室73相连。这个预定度数低于液罐1或其一部分71的抵抗压力强度。因而防止了室73或液罐1的压力超过预定度数或超过液罐1的抵抗压力强度，结果防止了液罐1被超过液罐1抵抗压力强度的压力所破坏。如果可变形构件72被损坏，绝缘液体5流向第二液罐11，结果绝缘液5不流向外边。压力响应排放阀12带有一个电开关，只有当压力响应排放阀12将室73连到第二液罐11时，电开关才切断流向电感器体4的电源。

在根据本发明的浸入绝缘液体中的电器的另一个实施例中，如图10所示，具有铁芯2和感应线圈3的电感器体4被包含在密封液罐1中。不可燃的和绝缘的液体5充满了液罐1和电感器体4间的液罐容积。液罐1含有用于冷却不可燃液体5的散热器6。至少有一个液罐容积调节装置7被安置在液罐1的上部用以调节能接收在液罐1中包围电感器体4的绝缘液体5的容积并为绝缘液体5加压。液罐容积调节装置7带有一波纹管（bellows）76，波纹管被固定在液罐1上，气体和液体不能通过该波纹管，它的内部与液罐1的内部相通与液罐1一起限定能接收绝缘液体5的液罐容积。由于波纹管76可变形来改变其内部容积，可接收液罐1中的绝缘液体5的容积也被改变。安置在液罐1与波纹管间的一个弹簧78通过一活塞盘77对波纹管76加压来调节波纹管76的形状，以便根据绝缘液体5的体积来调节液罐容积，在液罐1里的绝缘液体5被加压至比如大于大气压（大约为0·1MPa）并小于0·3MPa。弹簧78的

压力被确定在使绝缘液体5在一适当程度以防止绝缘液体5汽化，甚至在由电感器体或包围液罐1的空气的热量所引起的绝缘液体5的温度增加时，也是如此。绝缘液体5完全充满液罐1中能接收绝缘液体5的容积。用于补偿绝缘液体5的体积变化的一个所需体V由下列式子来确定：

$$V = \beta * (\vartheta' - \vartheta) * V_L$$

$$= 15.4 * 10^{-4} * 105 * V_L = 0.16 V_L$$

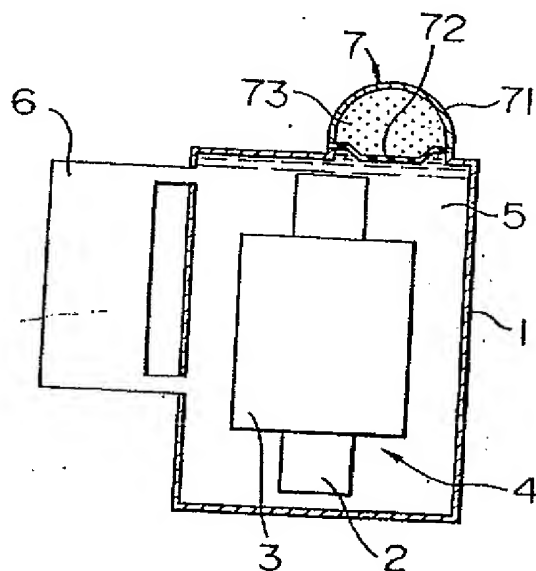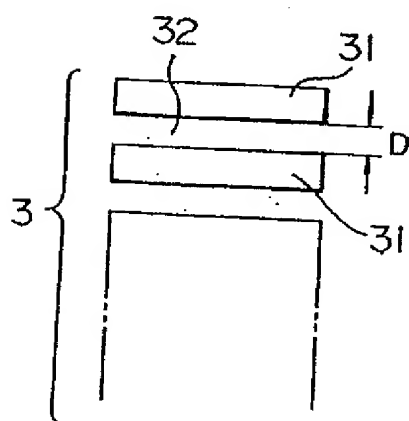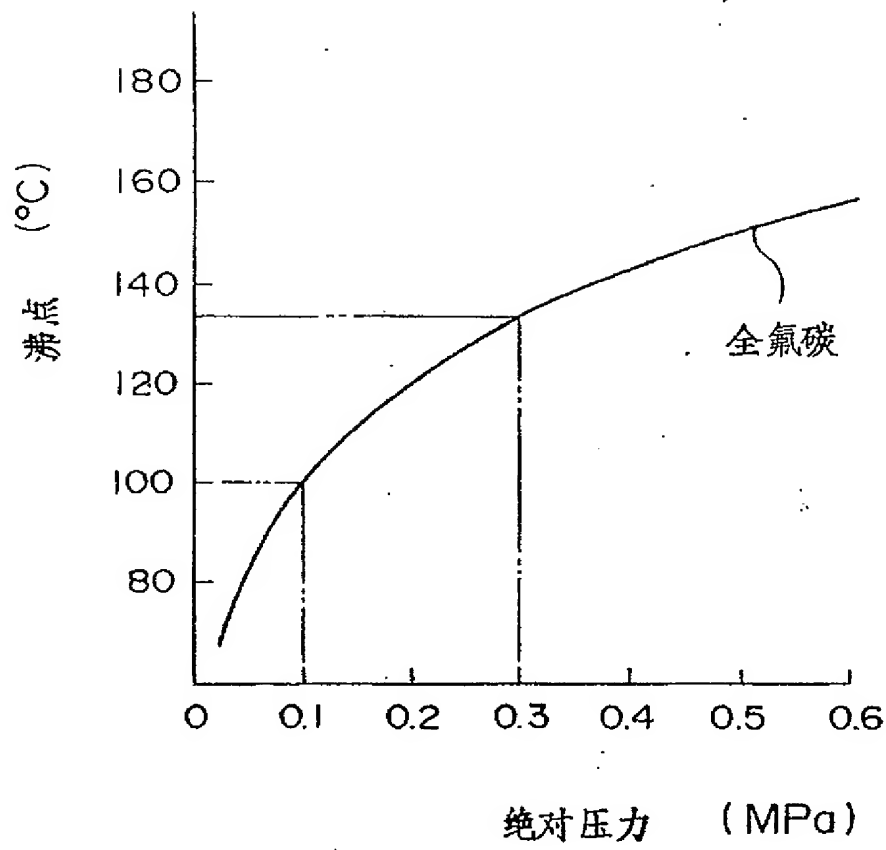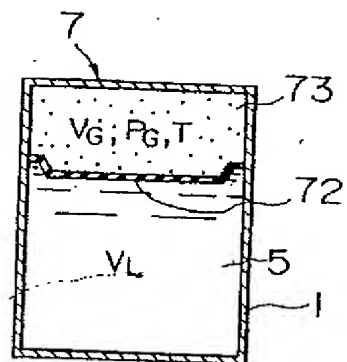因而，波纹管76的可调节内部体积可以是绝缘液体的16%，这样浸入绝缘液针电器的尺寸可以是小的

图 1

图 2

图3

全氟碳

绝对压力 （MPa）

图 4

图 5

V_G; P_G, T 73

72

V_L 5

I

V_G', P_G', T' 73

72

V_L' 5

I

图 6

6 5 7

74

73

75

I

3 2 4

图 7

图 8

图 9

图 10
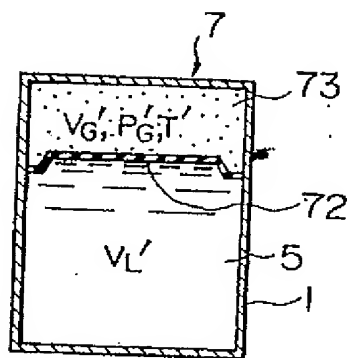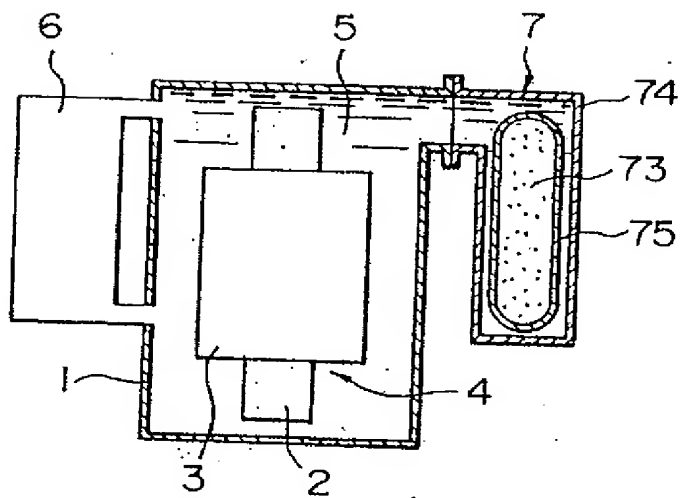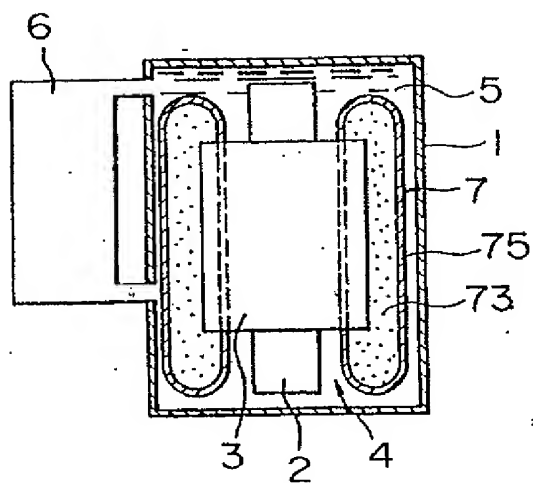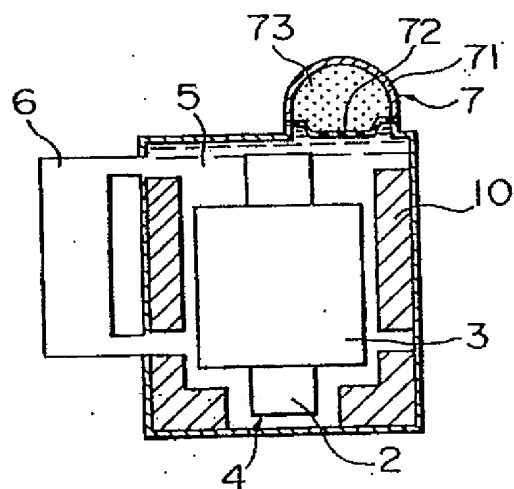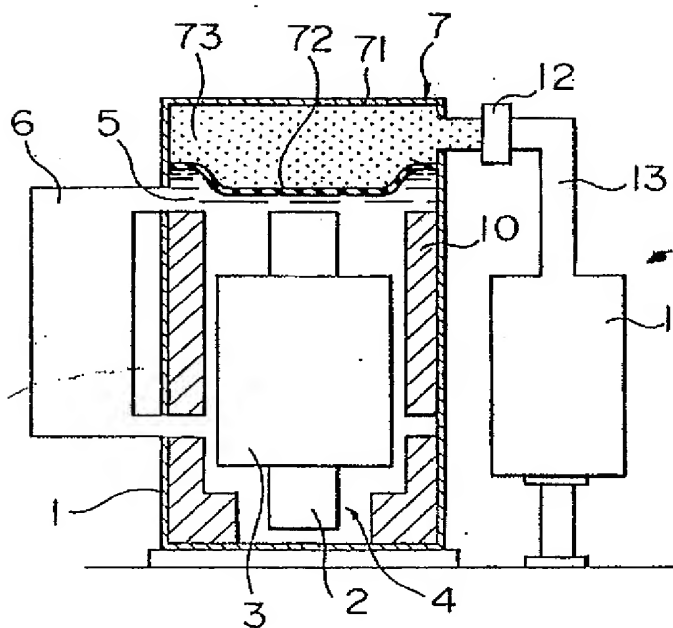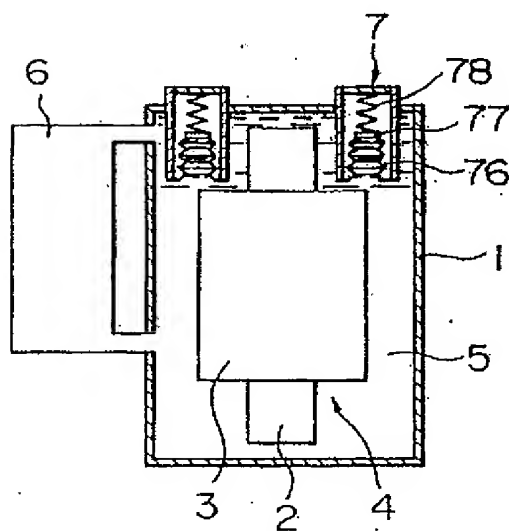
ELECTRIC APPLIANCE SOAKED IN INSULATING LIQUID

BACKGROUND OF THE INVENTION AND RELATED ART STATEMENT

The present invention relates to an electrical machine which is immersed in non-flammable insulating liquid for cooling the electrical machine and for increasing insulating strength in the electrical machine.

A prior art insulating-liquid immersed inductor comprises, as shown in Japanese Patent Unexamined Publication No. 63-241909, an inductor body including an iron core and a coil, and a hermetically sealed tank in which the inductor body is arranged, non-flammable insulating liquid fills a part of a space between the inductor body and the hermetically sealed tank to immerse the inductor body therein, and the other part of the space is filled by pressurized insulating gas. A part of the pressurized insulating gas is absorbed in the non-flammable insulating liquid so that the volume of the pressurized insulating gas decreases in the tank.In the above prior art insulating-liquid immersed inductor, when the pressure in the hermetically sealed tank is decreased according to the decrease of temperature in the tank, the absorbed insulating gas returns to gas, so that the insulating-liquid includes many number of bubbles therein. The bubbles of the insulating gas causes the insulating strength to decrease in the inductor, because the insulating strength of the insulating gas is lower than that of the insulating liquid between the coated wires of the inductor.

OBJECT AND SUMMARY OF THE INVENTION

The object of the present invention is to provide an insulating-liquid immersed electrical machine in which the insulating-liquid does not include or absorb gas and is prevented from vaporizing.

According to the present invention, an insulating-liquid immersed electrical machine comprises, an electrical machine, a hermetically sealed tank containing the electrical machine, and insulating-liquid arranged between the electrical machine and the tank, wherein the tank includes deformable means through which gas and liquid cannot pass and whose shape is variable so that a receiving volume capable of receiving the insulating-liquid between the tank and the electrical machine is variable, the insulating-liquid fills completely the receiving volume in the tank, and the insulating-liquid immersed electrical machine further comprises pressurizing means for adjusting the shape of the deformable means so that the pressure of the

insulating-liquid in the tank is kept at a suitable degree for preventing the insulating-liquid from vaporizing.

In the insulating-liquid immersed electrical machine according to the present invention, since the tank includes the deformable means through which gas and liquid cannot pass and whose shape is variable so that the receiving volume capable of receiving the insulating-liquid between the tank and the electrical machine is variable and since the insulating-liquid fills completely the receiving volume in the tank, the receiving volume does not include gas therein and the gas is not absorbed by the insulating-liquid in the receiving volume. And since the tank includes the deformable means whose shape is variable so that the receiving volume is variable, the deformable means compensates a change of the receiving volume even when the shape of the tank and the volumes of the electrical machine and insulating-liquid change according to a change in temperature.And further, since the insulating-liquid immersed electrical machine further comprises the pressurizing means for adjusting the shape of the deformable means so that the pressure of the insulating-liquid in the tank is kept at a suitable degree for preventing the insulating-liquid from vaporizing, the insulating-liquid does not vaporize even when the receiving volume is changed.Therefore, gas bubbles decreasing insulating strength in the electrical machine is not generated in the insulating-liquid.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a partially cross-sectional view showing an embodiment of the insulating-liquid immersed electrical machine according to the present invention.
Fig. 2 is a schematic cross-sectional view showing a part of a coil used in the insulating-liquid immersed electrical machine according to the present invention.
Fig. 3 is a diagram showing boiling point characteristics relative to absolute pressure in perfluorocarbon liquid used in the insulating-liquid immersed electrical machine according to the present invention.
Figs. 4 and 5 are partially cross-sectional views showing change in shape of deformable means of the insulating-liquid immersed electrical machine according to the present invention, which deformable means is deformed according to change in temperature.
Figs. 6 to 10 are partially cross-sectional view showing the other embodiments of the insulating-liquid immersed electrical machine according to the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

In an embodiment of the insulating-liquid immersed electrical machine according to the present invention, as shown in Fig. 1, an inductor body 4 having an iron core 2

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and a coil 3 is contained by a hermetically sealed tank 1. Incombustible and insulating liquid 5 fills a volume between the tank 1 and the inductor body 4 to cool the inductor body 4 and to increase insulating strength in the inductor body 4. The non-flammable liquid is, for example, perfluorocarbon liquid whose main component is C8F16O. The tank 1 contains a radiator 6 for cooling the incombustible liquid 5 heated by the operation of the inductor body 4.Tank volume adjusting means 7 is arranged at an upper portion of the tank 1 to adjust a volume capable of receiving the insulating-liquid 5 for surrounding the inductor body 4 in the tank 5 and to pressurize the insulating-liquid 5, for example, more than the atmospheric pressure. The tank volume adjusting means 7 has a hermetically sealed cover 71 fixed to the tank 1 and a flexible or deformable member or sheet 72 through which gas and liquid cannot pass, which defines a chamber 73 together with the cover 71 and which defines the tank volume capable of receiving the insulating-liquid 5 together with the tank 1. Since the deformable member 72 can deform, the volume capable of receiving the insulating-liquid 5 in the tank 1 is changed. Pressurized gas 73 (The chamber 73 and the pressurized gas arranged therein are donated by the identical reference numerals "73".) is inserted into the chamber 73 to press the deformable member 72 and to adjust the shape of the deformable member 72 so that the tank volume is adjusted according to the volume of the insulating-liquid 5 and the insulating-liquid 5 in the tank 1 is pressurized, for example, more than the atmospheric pressure (about 0.1 MPa) and less than 0.3 MPa. The pressure of the gas 73 is determined to set the pressure of the insulating-liquid 5 at a suitable degree for preventing the insulating-liquid 5 from vaporizing even when the temperature of the insulating-liquid 5 is increased by the heat of the inductor body 4 or by the air surrounding the tank 1. The gas 73 may be, for example, atmosphere or insulating gas or inert gas.Since the gas 73 and the insulating-liquid 5 cannot pass through the deformable member 72 and the insulating liquid 5 fills completely the tank volume capable of receiving the insulating-liquid 5 in the tank 1, gas is not included or absorbed by the insulating-liquid 5. Therefore, bubbles of the gas is not generated, even when the temperature of the insulating liquid 5 is increased and/or the pressure of the insulating liquid 5 in the tank is decreased.

In the structure of the coil 3 as shown in Fig. 2, an passage 32 for the insulating-liquid 5 extends radially between coated wires 31 of the coil 3. A width of the insulating liquid passage 32 is indicated by D in Fig. 2.

The insulating-liquid 5 flows in the passage 32 to cool the inductor body 4 and the temperature of the insulating-liquid 5 is increased by the heat generated by the operation of the inductor body 4. The heated insulating-liquid 5 flows to the radiator 6 for cooling the insulating-liquid 5 so that the temperature of the insulating-liquid 5 surrounding the inductor body 4 is kept at a low degree. Therefore, the insulating-liquid 5 can cool the inductor body 4 effectively and the insulating characteristic of the insulating-liquid 5 is not decreased. Since the insulating-liquid 5 is pressurized, for example, more than 0.1 MPa and less than 0.3 MPa through the

deformable member 72 by the pressurized gas 73, the boiling point of the insulating-liquid 5 is set at a high degree as shown in Fig. 3.Therefore, bubbles of the vaporized insulating liquid is not generated, for example, in the insulating liquid passage 32 between the coated wires 31 of the coil 3, even when the inductor body 4 begins to operate or even when the electrical current flowing in the coated wires 31 increases rapidly, that is, even when the temperature of the insulating liquid 5 is increased rapidly. In this way, the insulating strength of the insulating liquid 5 is always kept at a high degree.

Further, though width D of a prior art insulating liquid passage is about 5 mm, the width D of the insulating liquid passage 32 according to the present invention may be small, for example, less than 2 mm, because the gas is not absorbed by the insulating liquid 5, the bubbles of the vaporized insulating liquid is not generated and the kinematic viscosity 0.8 cst of the perfluorocarbon liquid ($C8F16O$) is significantly smaller than the kinematic viscosity 7.5 cts of mineral oil. Therefore, the size of the inductor body 4 may be small.

If the pressure of the insulating liquid 5 and the pressure of the gas 73 is kept between 0.1 MPa and 0.3 MPa, the tank 1 and the cover 71 do not require a special structure for resisting pressure.

When the insulating liquid 5 is perfluorocarbon liquid, a suitable volume of the chamber 73 defined by the deformable member 72 with the cover 71 is determined as follows. Please refer to Figs. 4 and 5. On the basis of Boyle's and charles' law, when surrounding temperature 8 is -25 DEG C, the volume of the insulating liquid 5 is VL, the volume of the gas 73 is VG, the pressure of the gas is PG, the temperature of the gas 73 is T as shown in Fig. 4, and when surrounding temperature theta is 80 DEG C, the volume of the insulating liquid 5 is VL min , the volume of the gas 73 is VG min , the pressure of the gas is PG min , the temperature of the gas 73 is T min as shown in Fig. 5, relations among these are shown by following formulas (1), (2) and (3).

$(PG*VG)/T = (PG min *VG min)/T$ (1)

$VG = X*VL$ (2)

$VG min = X*VL - VL* beta *(theta min - theta)$ (3)

(X is a rate of VG relative to VL. beta is the expansion coefficient of the insulating liquid 5.)

When the formulas (2) and (3) are combined with 15 the formula (1), $(PG*X*VL)/T$ = PG min *VL*{X- beta *(theta min - theta)}T. (4)

$X/\{X- beta *(theta min - theta)\} = (PG min *T)/(PG*T min)$ (5)

According to the formula (5), when PG is 0.1 MPa, T is 253 (273-20) DEG k, theta is -20 DEG C, PG min is 0.3 MPa, T min is 358(273+85) DEG k, theta min is 85 DEG C and beta is $15.4*10^{-4}$(1/ DEG C),

X = 0.3

Therefore, the suitable volume of the chamber 73 is 30 percent of the volume of the insulating liquid 5, when the surrounding temperature theta is -25 DEG C.

In this embodiment, the reliability of the insulating strength is improved and the stable insulating characteristic is kept. Further, the size of the coil may be small, the tank does not require the special structure for resisting pressure, and a low-cost insulating-liquid immersed electrical machine can be provided.

Another embodiment of the insulating-liquid immersed electrical machine according to the present invention, as shown in Fig. 6, has the tank volume adjusting means 7 including a case 74 which is detachably mounted on the tank 1 and whose inside communicates with the inside of the tank, and a valloon-shaped deformable member 75 whose volume is variable, in which the pressurized gas 73 is inserted to adjust the volume of the valloon-shaped deformable member 75 for pressurizing the insulating-liquid 5 and which is contained by the case 74. The gas 73 and the insulating-liquid 5 cannot pass through the deformable member 75 and the insulating liquid fills completely a volume capable of receiving the insulating-liquid 5 in the tank 1 and the case 74. The case 74 may be arranged at an upper portion of the tank 1 or at a side portion thereof. In this structure, the insulating strength is improved and the size of the insulating-liquid immersed electrical machine may be small during transportation thereof because of the detachable structure of the tank volume adjusting means 7.

The other embodiment of the insulating-liquid immersed electrical machine according to the present invention, as shown in Fig. 7, has the tank volume adjusting means 7 including a valloon-shaped deformable member 76 whose outer volume is variable, in which the pressurized gas 73 is inserted to adjust the volume of the valloon-shaped deformable member 75 for pressurizing the insulating-liquid 5 at a suitable degree and which is contained by the tank 1. The gas 73 and the insulating-liquid 5 cannot pass through the deformable member 75 and the insulating liquid 5 fills completely a volume capable of receiving the insulating-liquid 5 surrounding the inductor body 4 in the tank 1. In this structure, the insulating strength is improved, the volume of the insulating-liquid 5 filling completely the volume capable of receiving the insulating-liquid 5 surrounding the inductor body 4 in the tank 1 may be small, and the volume of the gas 73 also may be small because the required volume of the insulating-liquid 5 is small. Therefore, the size of the insulating-liquid immersed electrical machine is small.

The other embodiment of the insulating-liquid immersed electrical machine according to the present invention, as shown in Fig. 8, has the structure shown in Fig. 1 and solid insulating members 10 arranged between the inductor body 4 and the tank 1. In this structure, the insulating strength is improved, the volume of the insulating-liquid 5 filling completely the volume capable of receiving the insulating-liquid 5

surrounding the inductor body 4 in the tank 1 may be small, and the volume of the gas 73 also may be small because the required volume of the insulating-liquid 5 is small. Therefore, the size of the insulating-liquid immersed electrical machine is small.

The other embodiment of the insulating-liquid immersed electrical machine according to the present invention, as shown in Fig. 9, has the inductor body 4 having the iron core 2 and the coil 3, the hermetically sealed tank 1 containing the inductor body 4 and the radiator 6. Tank volume adjusting means 7 is arranged at an upper portion of the tank 1. The tank volume adjusting means 7 has the deformable member 72 which defines the chamber 73 together with the portion 71 of the tank 1 and which defines the tank volume capable of receiving the insulating-liquid 5 together with the tank 1. Pressurized gas is inserted into the chamber 73. The insulating liquid 5 fills completely the tank volume capable of receiving the insulating-liquid 5 in the tank 1. The solid insulating members 10 are arranged between the inductor body 4 and the tank 1.A second tank 11 is connected to the chamber 73 through a conduit 13 and a pressure response discharge value 12 which connects the chamber 73 to the second tank 11 only when the pressure in the chamber 73 increases more than a predetermined degree. The predetermined degree is set less than the resisting pressure strength of the tank 1 or the portion 71 thereof. Therefore, the pressure in the chamber 73 or in the tank 1 is prevented from increasing more than the predetermined degree or the resisting pressure strength of the tank 1, so that the tank 1 is prevented from destroyed by the pressure more than the resisting pressure strength of the tank 1. And if the deformable member 72 is destroyed, the insulating-liquid 5 flows into the second tank 11 so that the insulating-liquid 5 does not flow to the outside.The pressure response discharge value 12 has an electrical switch which cuts off the supply of electrical current to the inductor body 4 only when the pressure response discharge value 12 which connects the chamber 73 to the second tank 11.

In the other embodiment of the insulating-liquid immersed electrical machine according to the present invention, as shown in Fig. 10, the inductor body 4 having the iron core 2 and the coil 3 is contained by the hermetically sealed tank 1. The non-flammable and insulating liquid 5 fills the tank volume between the tank 1 and the inductor body 4. The tank 1 contains the radiator 6 for cooling the non-flammable liquid 5. At least one tank volume adjusting means 7 is arranged at an upper portion of the tank 1 to adjust a volume capable of receiving the insulating-liquid 5 for surrounding the inductor body 4 in the tank 5 and to pressurize the insulating-liquid 5.The tank volume adjusting means 7 has a bellows 76 which is fixed to the tank 1, through which gas and liquid cannot pass and whose inside communicates with the inside of the tank 1 to define the tank volume capable of receiving the insulating-liquid 5 together with the tank 1. Since the bellows 76 can deform to change its inside volume, the volume capable of receiving the insulating-liquid 5 in the tank 1 is changed. A spring 78 arranged between the tank 1 and the bellows pressures through a piston plate 77 the bellows 76 to adjust the shape of the bellows 76 so that the tank volume is adjusted according to the volume of the insulating-liquid

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5 and the insulating-liquid 5 in the tank 1 is pressurized, for example, more than the atmospheric pressure (about 0.1 MPa) and less than 0.3 MPa. The pressing force of the spring 78 is determined to set the pressure of the insulating-liquid 5 at a suitable degree for preventing the insulating-liquid 5 from vaporizing even when the temperature of the insulating-liquid 5 is increased by the heat of the inductor body 4 or by the air surrounding the tank 1. The insulating liquid 5 fills completely the tank volume capable of receiving the insulating-liquid 5 in the tank 1. A required volume V for compensating a change in volume of the insulating liquid 5 is determined by a following formula.

$$V = beta *(theta\ min - theta)*VL = 15.4*10<-><4>*105*VL = 0.16\ VL$$

Therefore, an adjustable inside volume of the bellows 76 may be 16 percent of the volume of the insulating liquid 5, so that the size of the insulating liquid immersed electrical machine may be small.